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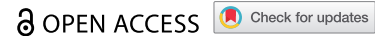


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CASE STUDY



Increasing cardio-thoracic productivity at Erasmus MC

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ABSTRACT

The Thoraxcenter of Erasmus MC started an improvement project in 2015 in order to increase the number of open-heart surgeries by 150 for three consecutive years (450 in total, +46%), and to decrease the access time from 12–14 to 2–3 weeks by the end of 2016. This was required to attain economy of scale in a highly competitive market. In this paper we describe the first year of the project, focusing on its structure and interventions taken, resulting in 165 additional open-heart surgeries carried out in 2016 and a significantly shorter access time of 2–3 weeks.

ARTICLE HISTORY

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1. Introduction

A focus on decreasing healthcare expenditures from government and insurance companies has resulted in numerous challenges and increased competition (Westert et al., 2009), also for cardiac surgery centres in the Netherlands. In order to provide the necessary regional cardiac surgical service, and to attain economy of scale, while acting in a highly competitive market, the Thoraxcenter of the Erasmus MC decided in 2015 to increase the number of open-heart surgeries by 150 in 2016, 2017 and 2018 (450 in total, +46%). Following budget negotiations with Erasmus' prevalent healthcare insurer, a goal of 150 additional operations was indeed set for 2016. In this paper, we discuss the improvement project that was carried out to enable the first wave of production increase for 2016.

The Erasmus MC is a tertiary university hospital, and the largest hospital in the Netherlands with (in 2016) approximately 1,300 beds, 750 physicians and 11,000 other (paramedical and non-medical) employees. The Thoraxcenter was founded in 1971, providing close cooperation between Cardiology and Cardio-thoracic Surgery. The Erasmus MC is situated in Rotterdam, which is in the south-west of the Netherlands, one of the most densely populated areas in the country. In 2015 there were eight other cardiac surgery centres within an 80 km radius; two of those centres situated within a 40 km radius (see Figure 1. Note that in the Netherlands, patients cannot visit a hospital without a referral from a GP or a medical specialist. For cardio-thoracic surgery, usually only cardiologists refer cardiac patients). The Thoraxcenter is a supra-regional referral centre for complex cardio-thoracic surgery, including (paediatric) cardiac and pulmonary transplantation and mechanical (paediatric)

cardiac support. By the end of 2018, all adult care in the Erasmus MC, including that for cardio-thoracic patients, has been concentrated in a new facility, but during the first year of the project, the Thoraxcenter was still situated in a separate facility. Several resources were specifically allocated to the department of Cardio-thoracic Surgery, namely four operating rooms (ORs), an ICU, a High/Medium care department and outpatient clinic facilities. In 2015, 989 open-heart surgeries were performed.

The cardio-thoracic surgeons faced several challenges, typical for their patient cohort: long surgery durations with a high level of variation, many (10%) urgent patients, and an intensive preparation of the patient prior to surgery. Also, overall efficiency, staff work pressure and utilisation of resources were a point of concern, while the Erasmus MC market share for open-heart surgery within its catchment area was relatively low (around 50%, compared to 85% for other cardiac surgery centres). Increasing Erasmus MC's market share to 85% would mean an annual increase of 455 open-heart surgeries per year.¹ The low market share was mainly due to the long access time² (12–14 weeks) for elective patients and accessibility issues. Referring hospitals perceived difficulties in contacting the attending cardio-thoracic surgeons to discuss patients. Also, the administrative aspects of transfer of patients from the referring hospital to the Erasmus MC was experienced as a complicated and time-consuming process. It was therefore not uncommon that patients from the Rotterdam-Rijnmond region were referred to other cardiac surgery centres with a shorter access time. In order to increase productivity, the number of patient referrals should be increased once the access time was normalised. This was therefore an important issue to address. In September 2015 a project was started

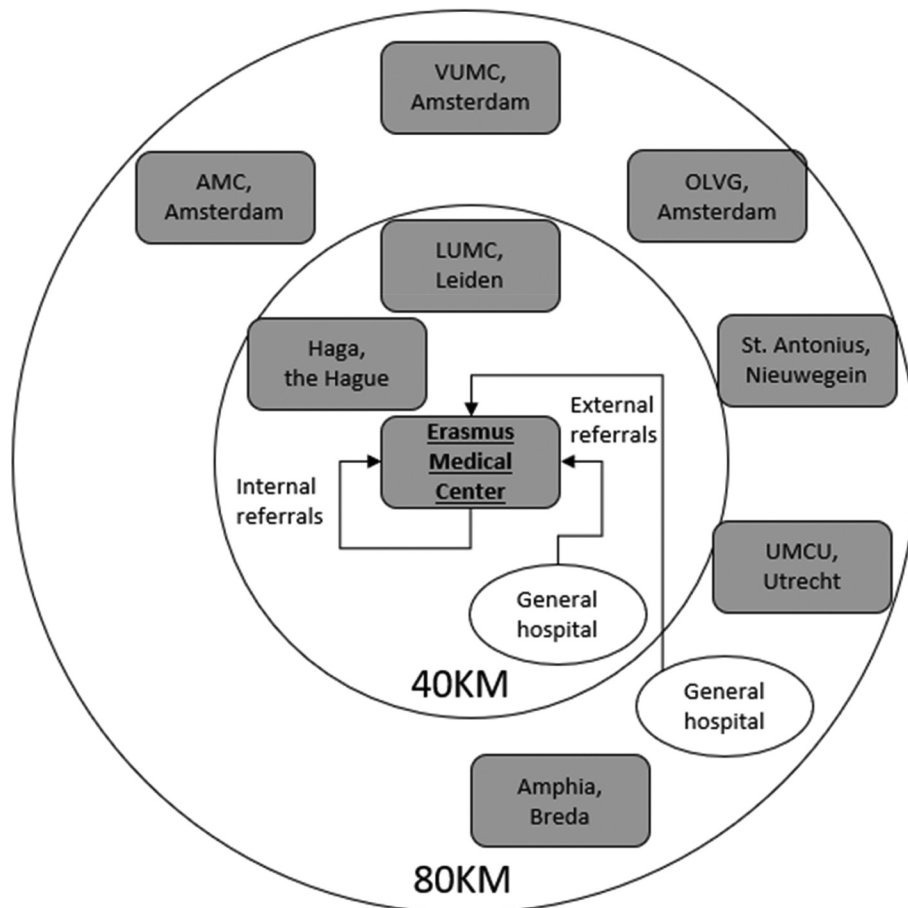


Figure 1. Cardiac-thoracic surgery centres in the south-west of the Netherlands (2015 situation).

by the Thoraxcenter to increase their efficiency and capacity whilst improving patient experience, thus enabling the 150 cases production increase. The board of the Erasmus MC fully supported the growth ambitions of the Thoraxcenter, since it aligned perfectly with the hospital's strategy to target specific, high-complex patient groups. This paper describes the first year of the project, discusses the interventions taken and highlights the results achieved in 2016.

2. Literature

Since an Operations Research & Management Science approach is often unfamiliar to medical staff, constant dialogue is necessary (Harper & Pitt, 2004). Model results are usually very promising, but successful implementation of Operations Research & Management Science solutions is still quite limited (Brailsford & Vissers, 2011). Here, the authors state that the contribution of a mathematical model often lies more in offering a system perspective, and that it can function as a tool to understand the effect of variation on performance. Resolving the actual problem at hand does not always require complex planning and scheduling algorithms. Instead, behavioural aspects should be taken into account more explicitly when developing Operations Research models

for healthcare applications (Kunc et al., 2020). Van Lent et al. (2012) studied the implementation of simulation results in healthcare, and conclude that implementation rates are low. Also, it is usually not clear if the results were actually implemented. According to Lukas et al. (2007), five elements are critical to successful transformation of patient care: (1) Impetus to transform; (2) Leadership commitment to quality; (3) Improvement initiatives that actively engage staff in meaningful problem solving; (4) Alignment to achieve consistency of organisation goals with resource allocation and actions at all levels of the organisation; and (5) Integration to bridge traditional intra-organisational boundaries among individual components. Insights from the aforementioned publications were used to ensure staff involvement and maximise the chances of a successful implementation.

Hulshof et al. (2012) provide an extensive overview of planning decisions in health care, together with related literature. Access time reduction is a complex topic and usually comprises many elements of process improvement. In general, in order to increase accessibility, available capacity should be maximally utilised and if necessary, additional capacity should be added. See for example, the surveys of Bai et al. (2018) on ICU capacity optimisation, Cardoen et al. (2009) on OR planning and scheduling, and Cayirli and Veral (2003) on outpatient

clinic scheduling. In the case of many urgent patients, two main strategies can be distinguished that ensure patient access and avoid cancellations or unused capacity at the same time. The first strategy is to dedicate one or several ORs to urgent cases (Bhattacharyya et al., 2006). The second strategy is to allocate part of the session in elective ORs to urgent cases (Wullink et al., 2007). Regardless of the strategy chosen, determining the required capacity for urgent patients can be challenging. In Zonderland et al. (2010) a queuing model is provided that quantifies the trade-off between unused OR time and elective patient cancellations, given demand of (semi-) urgent patients.

3. Methods

In this section, we will elaborate on the methods used in the project. We briefly discuss the project structure and decision-making process and then focus on the interventions taken. In September 2015, a project and steering group were created; the composition of both groups is given in Table 1. The project group met on a weekly basis and discussed all topics relevant for the project. Major decisions were escalated to the steering group meeting, which was planned bi-monthly. Also, four workshops were organised, in order to align working routines among the cardio-thoracic care chain. If required, staff from outside the project group attended as well. The topics of the workshops

were 1) pre-operative preparation of patients; 2) the surgical planning process; 3) planning routines; and 4) OR working routines. Elements from Lean methodology, such as brown paper sessions, value stream mapping and Kaizen were used to create an environment of continuous improvement (see for example, Brandao de Souza (2009) for trends and approaches of Lean applications in healthcare).

As said, the project's goals were twofold, namely 1) increase the number of open-heart surgeries by 25% by the end of 2016 (as compared to 2015); and 2) decrease patient's access time to 2–3 weeks as soon as possible (note that an access time of up to 2 weeks for elective cardiac surgery was required to prepare the patient for surgery). To attain these goals, five interventions related to the steps in the thoracic patient's flow (see Figure 2) were identified, which will be explained in the subsequent paragraphs.

3.1. Intervention 1 – increase capacity

Additional OR staff and anaesthesiologists were hired to increase OR opening hours. Instead of having two rooms available for elective procedures from 8AM-4PM and two rooms from 8AM-5PM, now two rooms were available from 8AM-5PM and two rooms from 8AM-7PM. Also, the OR manager adapted the shifts of OR staff to accommodate the new opening hours. The purpose of increasing OR opening hours was twofold. First, in the case of

Table 1. Project and steering group composition. All managers within the project group were working solely for the Thoraxcenter (A# = author ID).

Project group	Steering group
<ul style="list-style-type: none"> ● Cardio-thoracic surgeon (deputy department head – A2) ● Cardio-thoracic surgeon (staff member – A5) ● Cardio-thoracic anaesthesiologist (A4) ● ICU physician (A3) ● Director of Thoraxcenter (A7) ● OR manager ● ICU manager ● High/Medium Care manager ● Outpatient clinic manager ● Project lead (A1) 	<ul style="list-style-type: none"> ● Cardio-thoracic surgeon (department head – A8) ● Director of Thoraxcenter ● Erasmus MC OR manager ● Director of OR, ED and ICU ● Project lead (A1)

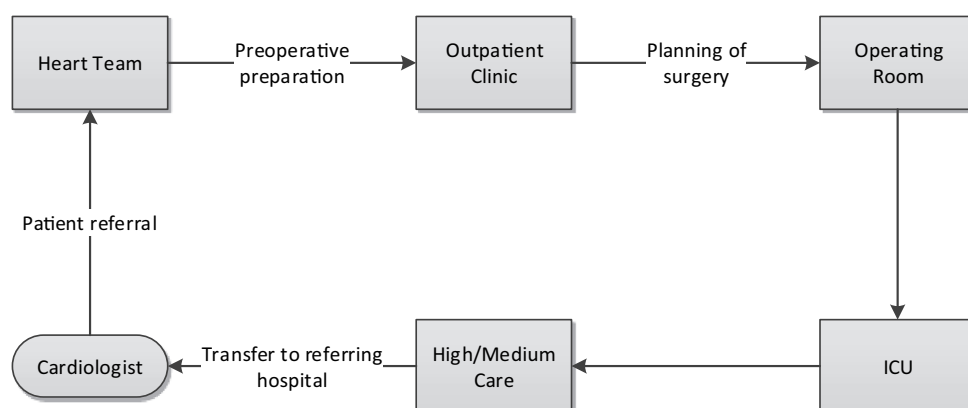


Figure 2. Steps in the thoracic patient's flow.

a long (>8 hours) individual surgery, the probability of staff working in overtime was decreased. Second, in the old situation, it would often happen that the first surgery of the day was finished at 1PM, leaving 3 hours of available OR capacity. With an average surgery duration of almost 5 hours, it would be a challenge to fill up this capacity. In the new situation, it was expected that it would be easier to make combinations of surgeries and thus use capacity more efficiently. Initially, it was intended to add three beds and associated staff to the ICU. However, due to significant (nursing) staff shortages in the Rotterdam-Rijnmond region, ultimately only a single bed could be added. The Medium Care experienced the same problems: 10 additional beds were planned but only four could be realised by mid-2015.

3.2. Intervention 2 – improve the preoperative patient preparation

In order to improve patient preparation, all pre-operative preparation activities were concentrated at the outpatient clinic and planned on the same day. This increased the overview of the process and decreased the number of times patients would need to visit the hospital. As a rule, patients could only be planned for surgery once all pre-operative preparation activities were completed. Guidelines for referring cardiologists were extended, extensively describing the required patient information and diagnostic tests to perform prior to referral, in order to speed up the preoperative process. When patients were discussed in the daily, multi-disciplinary heart team meeting, the referring cardiologist would be informed immediately if and when his/her patient would be planned for surgery.

3.3. Intervention 3 – improve the planning & scheduling process

As in many healthcare organisations, paradoxically staff in all departments of the Thoraxcenter experienced high work pressure, while at the same time a significant part of capacity was unused. Several measures were identified to improve the planning & scheduling process, which should lead to an increase in utilisation. These measures were related to the planning of surgeons, elective patient scheduling and improving the day-to-day operations.

To allow the administrative office to plan surgeries 2–3 weeks ahead, such that combinations of surgeries, resulting in efficient use of OR time (see also intervention 1) were possible, a 2-month rolling-horizon planning was set up for the surgeons. It was expected this would also decrease the number of changes in the OR schedule, due to last-minute specific surgeon unavailability. A horizon of 2 months was chosen, since this allowed for enough planning flexibility, especially for complex surgeries that were performed by multiple surgeons and which required planning several weeks or even months

ahead. A planning horizon of more than 2 months was considered as too inflexible by the surgeons. Due to the long surgery duration and small number of ORs, the scheduling of elective patients was quite straightforward – at most three cases could be scheduled in one OR per day. To support the planning office in making combinations of surgeries (i.e., one long surgery, two semi-long surgeries or three short surgeries), a colour system was introduced. The expected duration of the surgery, together with the anticipated variance in duration, resulted in a colour label. Based on historical data, a blueprint schedule was developed, defining the colour combinations allowed and order in which the surgeries should be scheduled. The elective OR schedule of week N would be finalised on Thursday morning of week N-1 in a planning meeting with all stakeholders involved (see Figure 3 for a summary of the OR scheduling process).

To improve the day-to-day operations, the new role of “the surgeon of the day” (SOTD) was introduced. This role alternates between all thoracic surgeons and improves accessibility and the quality of patient referrals. The SOTD is not scheduled for OR nor outpatient clinic consultations and is the main point of communication for referring cardiologists. The SOTD is responsible and has the mandate to decide upon the final OR schedule of that day, and makes the decision which elective and urgent patients to schedule in the “urgent” OR IV at 7AM. This set-up eliminated the fuzzy communication between the planning office, anaesthesiologists, surgeons and other staff about changes in the schedule. Due to the alternating nature of the SOTD role, this “decision power” is equally shared among all surgeons. The SOTD also hosts a short, daily planning meeting at 10AM. In this meeting, the progress of ongoing surgeries and possible bottlenecks are discussed with the anaesthesiologist on call and the OR, ICU, High/Medium care coordinators. Also, the attendees briefly reflect on the previous day. Such “team huddles” are part of the Lean methodology (see for example, Mannon, 2014). A process feedback loop was introduced, with the OR coordinators started filling in day reports at the end of their shift, describing the progress of the OR planning of the day. The day report lists for each patient planned if the surgery commenced, if not why, the planned and realised surgery starting time, the surgery duration and any remarks or process complications. This information is also registered for patients who were added to the program. The report is discussed the following day during the 10AM planning meeting. As a result, bottlenecks could be identified and resolved quickly.

3.4. Intervention 4 – allocate capacity to urgent patients

Another challenge was the scheduling of urgent cases (10% of patients). To determine the required capacity for urgent patients in the OR schedule, the queuing

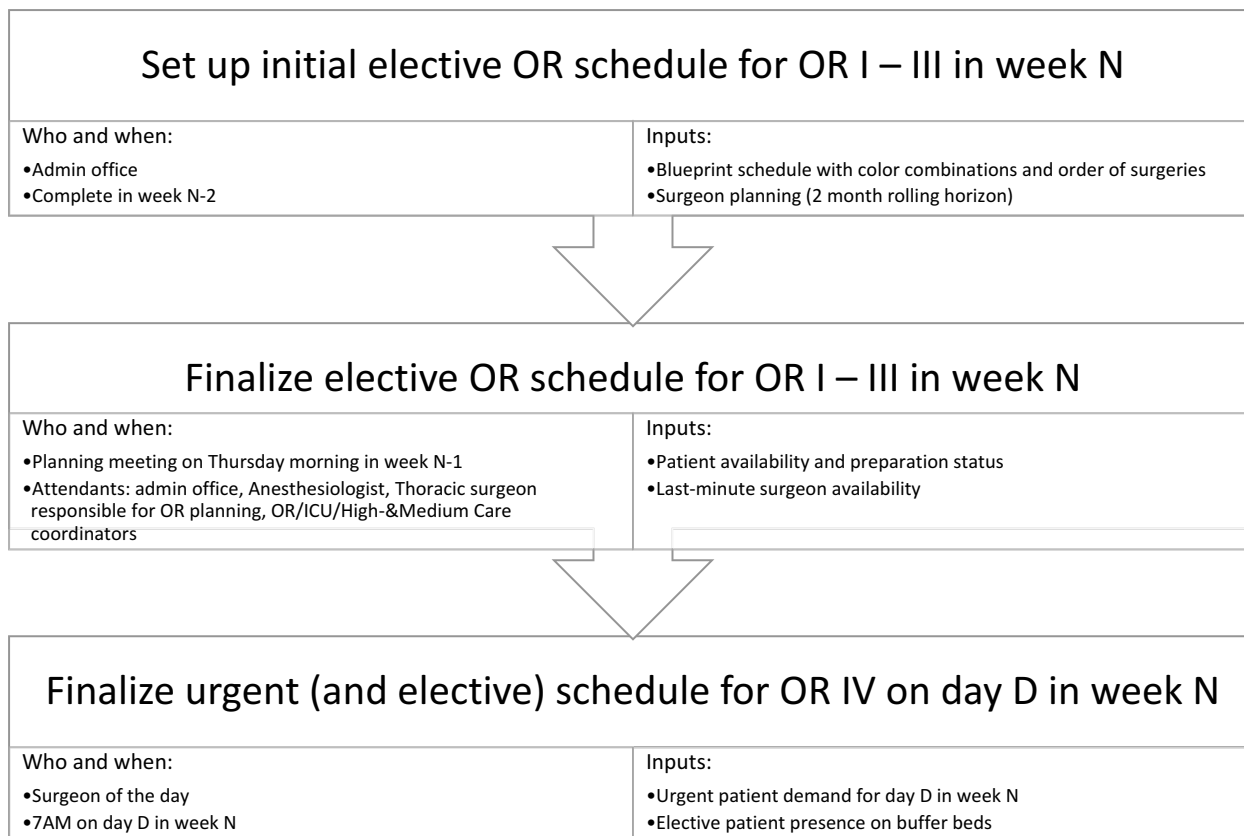


Figure 3. The OR scheduling process.

model described in Zonderland et al. (2010) was used as inspiration. Due to the size of the facilities (four ORs) and with regard to surgery duration, determining the amount of OR capacity to allocate to urgent patients was a delicate process. Analysis of all urgent cases in 2014 and the first half of 2015 ($N = 546$) showed that the probability of having more than one urgent case on an arbitrary day is 9%, while the probability of having none or one urgent case would be 64% and 27%, respectively. Further analysis showed that on average once per month two urgent cases would require surgery on the same day during regular OR opening hours. This confided the project group that earmarking one OR creates enough capacity for the urgent cases, while most of the time elective patients can use this OR capacity. In order to make sure OR capacity would be used efficiently, two “open-ticket” beds were created on the Medium Care, which were constantly occupied with two elective patients being on call and ready for surgery. If there would be no urgent patients present in the early morning, the empty slots were filled with patients from the open-ticket beds, thus introducing more flexibility in both patient demand and available capacity.

3.5. Intervention 5 – increase the number of patients referred to the Thoraxcenter

An access time of 12–14 weeks indicates that there is – at least in theory – a “patient buffer”. In order to determine

the patient volume related to the prolonged access time, the waiting list was checked thoroughly and patients who did not need treatment anymore (for example, because they were already treated in a different centre) were removed. This exercise decreased the length of the list with 15%. The remaining waiting list thus allowed for a temporary production increase, but for a sustainable result, an immediate increase in the number of patients referred to the Thoraxcenter was required as well. Therefore, the surgeons started to actively reach out to the referring cardiologists, communicating that the centre increased its capacity, improved the planning and scheduling process, and was thus able to treat more patients.

4. Results

In the first weeks of 2016, the main focus was on the implementation of the interventions and on responding to problems that occurred. Immediately (see Table 2) production levels could be increased. Many of the new routines were considered as usual practice within 2 weeks. Especially the introduction of the SOTD, the daily meeting at 10AM and the two-month rolling horizon surgeon planning were perceived as major improvements by all stakeholders. The day reports were discussed and altered several times. In order to closely manage the process, the project group continued their weekly meetings.

Table 2. The number of open-heart surgeries performed per month in 2015 & 2016.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	X	SD	CV
2015	77	74	101	73	72	89	82	78	90	84	89	80	989	82.42	8.61	0.10
2016	98	100	104	92	91	97	89	86	109	85	108	95	1154	96.17	8.03	0.08
δ	21	26	3	19	19	8	7	8	19	1	19	15	165	13.75	-0.58	-0.02

N, average (X), standard deviation (SD) and coefficient of variation (CV) for 2015 & 2016. The coefficient of variation is calculated by SD/X and is an indicator for the dispersion around the mean. A lower CV means a more stable process.

As is shown in Table 3, the number of open-heart surgeries performed in 2016 was higher than in 2015 (1154 vs. 989, + 17%), while the total number of surgeries performed increased from 1551 to 1737 (+12%). Therefore, the production increase ($N = +186$) was, as intended, mainly related to the increase in the number of open-heart surgeries ($N = +165$, 89% of the increase). The patient's access time decreased from 12–14 weeks in 2015 to 2–3 weeks in the first quarter of 2016 and remained more or less stable for the rest of the year. From Table 2 it is obvious that the variation in the number of open-heart surgeries performed per month is still existent and decreased only a little. This indicates that the stability of the planning process can be further improved. The project did not influence the average surgery duration (95% CI for 2015 = [4:36; 4:50] vs. [4:40; 4:52] for 2016), while the relative amount of urgent cases and patient cancellations both decreased with 2%. Since the access time remained constant over 2016, we can conclude that on average 17% more patients were attracted. The capacity increase that was realised in 2016 consisted of a 14% overall increase in nursing & OR staff, an 8% overall increase in beds, while

the available OR time was increased with 18%. The bed utilisation at the ICU decreased from 89% to 74%, caused by the additional bed added to the ICU and the decrease in patient's length of stay.

5. Discussion & conclusions

As discussed earlier, successful implementation of Operations Research & Management Science solutions is limited (Brailsford & Vissers, 2011). The goals for the first year of this project were 1) 150 additional open-heart surgeries in 2016; and 2) decrease of the access time to 2–3 weeks. Both goals were achieved. The potential throughput which could have been realised is difficult to quantify, due to the different levels in capacity increase that were achieved. As with many interventions performed in a practical (real-life) setting, the effect of a single intervention cannot be measured in isolation. When removing bottlenecks from a process, new bottlenecks will come up and need to be eliminated subsequently (Goldratt & Cox, 1984). Therefore, it is important to focus on continuous process improvement and monitor the process constantly. Next, to the increase

Table 3. Results for 2015 compared with 2016.

Topic	Data item	2015	2016
Production	Openheart surgeries performed	989	1,154(+17%)
	Total surgeries performed	1,551	1,737(+12%)
Access time	Number of weeks	12–14	2–3
	Employee resources ¹		
Employee resources ¹	OR staff (fte) ²	46.8	55.1(+18%)
	ICU staff (fte)	22.3	26.4(+18%)
	HC/MC staff (fte) ³	46.8	53.1(+13%)
	Surgeon staff (fte) ⁴	10.0	10.0
	Anaesthesiologist staff (fte) ^{4,5}	7.7	8.3 (+8%)
	Total	133.6	152.9(+14%)
Physical resources	OR rooms	4	4
	OR opening hrs. per week	170	200(+18%)
	ICU beds	6	7(+17%)
	HC/MC beds	30/34 ⁸	34(+7%)
Performance – OR	Number of cases with surgery duration registered	1,535(99%)	1,706(98%)
	Average surgery duration ⁶ [St. Dev]	4:43[2:17]	4:46[2:11]
	Urgent cases	160(10%)	133(8%)
	Patient cancellations ⁷	239(15%)	222(13%)
Performance – ICU	Bed utilisation	89%	74%
	Average length of stay (days)	2.6	2.4(-8%)
Performance – HC/MC	Bed utilisation	77%	77%
	Average length of stay (days)	8.6	7.3(-15%)

¹ Employee resources are measured in effective FTE; i.e., how many staff was actually employed, excluding those on sick- or maternity leave; ² OR staff includes OR nurses, OR assistants and trainees, anaesthesia assistants, perfusionists, care assistants, management and admin staff; ³ HC/MC staff includes nurses, trainees, care assistants, management and admin staff; ⁴ The physicians spend a significant amount of their time on other tasks such as teaching, research, management duties and committee or board memberships; ⁵ The anaesthesiologists were understaffed in January 2016; few shifts were taken over by general anaesthesiologists from the EMC OR department and children ICU physicians for the direct recovery after children's surgeries; ⁶ Surgery duration: the total length of stay of the patient on the OR complex, including anaesthesia and pre-surgical preparation (wheels in – wheels out), measured over all surgeries; ⁷ Patient cancellation: surgery postponed to other day or cancelled entirely. Including patients added (and subsequently cancelled) once the OR schedule for the next week was "finalised" on Friday afternoon; ⁸ The number of HC/MC beds was increased from 30 to 34 mid-2015.

in capacity, there were a couple of other elements that contributed strongly to the production increase. The constant dialogue with staff (Harper & Pitt, 2004), and the involvement of clinical leadership by having two surgeons in the project group, was crucial in order to implement the required process changes. Another key element in this project was the quick decision-making process during the weekly project group meetings, together with the sense of urgency perceived by all stakeholders and the close monitoring of the project. Note that no complex planning & scheduling algorithms were implemented, but the underlying methodology (Zonderland et al., 2010) and related knowledge and skills, applied by the project consultants, were very helpful in realising these results. The importance of a dedicated team, not only for this project, but also in the OR, with active involvement of the professionals, was essential for the success of this project. Explaining the strategic goals and facilitating the project was essential in motivating staff. The measures taken were easy to understand, easy to convince, and easy to implement.

Ultimately, an increase of 300 open-heart surgeries (+30%) was realised. This was mainly due to the limited growth in referrals. Since there is fierce competition between the cardiac surgery centres surrounding the Erasmus' Thoraxcenter, it was challenging to attract additional patients. Also, staff shortages (nursing and OR) in the Rotterdam-Rijnmond region did not allow for further capacity increase. In order to address the capacity availability issues, the hospital management decided to incorporate the Thoraxcenter in the newly built hospital in 2017–2018, aiming for further staff and OR efficiency as well as improvement of the IT landscape to support the planning process.

Notes

1. The population of Erasmus MC's catchment area (Rotterdam-Rijnmond) was at that time approximately 1.3 M people. In the Netherlands, around 1,000 open-heart surgeries are performed per 1 M people. An increase in market share of 35% equals $1.3 * 1,000 * 0.35 = 455$ additional open heart surgeries per year.
2. We define access time as the time interval between the moment of referral and the day of the surgery.

Disclosure statement

During this project, A1 and A6 were affiliated with Medtronic. Medtronic did not supervise this project, neither had any influence on the execution nor the results.

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